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(54) **ANALYZING THE INTERNAL PRESSURE OF CONTAINERS**

ANALYSE DES INNENDRUCKES VON BEHÄLTERN

ANALYSE DE LA PRESSION INTERNE DE CONTENEURS

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US-A- 4 869 097 **US-A- 5 353 631**
US-A- 5 591 900 **US-A- 5 675 074**

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Description

[0001] This invention generally relates to methods and apparatus for analyzing the internal pressure of containers and more particularly to methods and apparatus that detect and compensate for signal distortions in performing such analyses, and/or permit certain limits used in such analysis to be reset automatically.

[0002] Food, beverage, and drug containers, for example, are often sealed under vacuum (e.g., coffee) or internal pressurization (e.g., beer). If biological contamination or seal failure occurs, the product quality may be significantly degraded and may be dangerous to consumers. Accordingly, manufacturers test the internal pressure/vacuum of containers before shipment to identify and remove defective containers.

[0003] Two non-intrusive testing techniques are shown in US-A-3 802 252 and US-A-5 353 631, both of which are assigned to Benthos, Inc. (BENTHOS is a Registered Trade Mark). Systems of the type described in these patents have been sold under the name TapTone (Registered Trade Mark). In such systems, a conductive surface of a closed container is vibrated without contact, using a pulsed magnetic field, and the resulting sound is analyzed to determine the pressure in the container. A microphone senses the resulting acoustic energy and converts it into an electrical signal. In US-A-3 802 252, analog electronics are used to determine whether the signal has a detectable level of energy within a pre-tuned frequency band. If a signal is detected within the band, it is inferred that the can is good. In US-A-5 353 631, a similar test is performed using digital signal processing (DSP) electronics and software.

[0004] US-A-5 675 074, describes a method and apparatus which are similar to those of US-A-5 353 631, but in which information representing the detected sound is processed to determine whether a frequency component of this information corresponds to a predetermined spectral frequency condition and whether an amplitude component of this information corresponds to a predetermined spectral amplitude condition. Only if the container meets both conditions is it deemed to have a proper internal pressure.

[0005] Because closed containers are complex vibratory systems which often exhibit nonlinear effects, it is not uncommon to find in the use of such systems that the acoustic return signals have been modulated by vibratory modes of the container other than the fundamental mode typically used to predict internal pressure. When such modulating distortions are present, the information contained in the acoustic signal has been corrupted by misleading information that can lead to false rejections of containers.

[0006] In one aspect, this invention provides a method and apparatus generally similar to those of the aforementioned US-A-5 675 074 but which allow for compensation of any modulation distortion present in the acoustic signatures used to characterize the internal pressure of containers.

[0007] Another problem with the methods and apparatus described in the aforementioned patents is that, even in a container filling line which is operating correctly, slow changes ("drift") in the operation of the line may causes corresponding changes in the internal pressure of the containers. If one simply operates the method of US-A-5 675 074 with permanently fixed upper and lower amplitude limits defining the predetermined spectral amplitude condition, the drift in the line may eventually cause a significant proportion of containers to be falsely rejected because they have amplitude components outside the acceptable range.

[0008] This invention provides a method and apparatus generally similar to those of the aforementioned US-A-5 675 074 but which allow for dynamically changing the amplitude limits used for judging internal pressure to allow for slowly varying changes in the upstream container filling process to optimize throughput without permitting the passage of reject containers.

[0009] Accordingly, in one aspect, this invention provides a method comprising inducing vibration in a surface of a closed container; detecting sound resulting from the vibration; deriving information representing the detected sound; determining whether a frequency component of the information corresponds to a predetermined spectral frequency condition; and determining whether an amplitude component of the information corresponds to a predetermined spectral amplitude condition. This method is characterized by testing the original information representing the detected sound to determine whether a modulating distortion is present therein, and if so compensating for the effects of the modulating distortion, thereby producing demodulated information; and is further characterized in that the determination, of whether the frequency component of the information corresponds to the predetermined spectral frequency condition, is carried out on the original information, if no modulating distortion has been found therein, but is carried out on the demodulated information, if modulating distortion has been found in the original information, and the determination, of whether the amplitude component of the information corresponds to the predetermined spectral amplitude condition, is carried out on the original information, if no modulating distortion has been found therein, but is carried out on the demodulated information, if modulating distortion has been found in the original information. This method may hereinafter be called the "demodulating method" of the invention.

[0010] In one form of this method, the determination of whether the amplitude component of the information corresponds to the predetermined spectral amplitude condition is made by comparing the amplitude component to a range of acceptable values delimited by a lower limit and an upper limit. This form of the method may comprise accumulating, from a plurality of containers inspected at the container inspection station and judged to be satisfactory by satisfying the predetermined spec-

tral frequency condition and the predetermined spectral amplitude condition, amplitude data for the amplitude components of the containers; analyzing the amplitude data to derive an average value and a deviation therefrom; and resetting at least one of the lower limit and the upper limit in dependence upon the average value and the deviation.

[0011] This invention also provides apparatus (which may hereinafter be called "demodulation apparatus") for carrying out the demodulation method of the invention. This apparatus, for analyzing the internal pressure of a closed container, comprises a vibrator for inducing vibration in a surface of the closed container; a sound detector for detecting sound resulting from the vibration; information derivation means for deriving information representing the detected sound; and a data processor arranged to: (a) determine whether a frequency component of the information corresponds to a predetermined spectral frequency condition; (b) determine whether an amplitude component of the information corresponds to a predetermined spectral amplitude condition; and (c) produce a first output signal if the frequency component and the amplitude component correspond to the predetermined spectral frequency and amplitude condition respectively, and a second output signal if the frequency component fails to satisfy the predetermined spectral frequency condition or the amplitude component fails to satisfy the predetermined spectral amplitude condition. This apparatus is characterized in that the data processor is also arranged to test the original information from the information derivation means to determine whether a modulating distortion is present in the original information, and if so to compensate for the effects of the modulating distortion, thereby producing demodulated information; and is further characterized in that the data processor is arranged to carry out steps (b) and (c) on the original information, if no modulating distortion has been found therein, but to carry out steps (b) and (c) on the demodulated information, if modulating distortion has been found in the original information.

[0012] In one form of such apparatus, the data processor is arranged to determine whether the amplitude component of the information corresponds to the predetermined spectral amplitude condition by comparing the amplitude component to a range of acceptable values delimited by a lower limit and an upper limit. The data processor is also arranged to accumulate, from a plurality of containers judged to be satisfactory by satisfying the predetermined spectral frequency condition and the predetermined spectral amplitude condition, amplitude data for the amplitude components of the containers, to analyze this amplitude data to derive an average value and a deviation therefrom, and to reset at least one of the lower limit and the upper limit in dependence upon the average value and the deviation.

[0013] In many cases, the methods and apparatus of the invention will be used with containers the surface of which is at least partially conductive, and with such containers the vibration is desirably induced by imposing a magnetic field on the surface. Thus, the apparatus desirably includes an electromagnetic field source, in the form of a conductive coil, for providing this magnetic field. The predetermined spectral frequency and spectral amplitude conditions may correspond to ranges of acceptable values; thus the predetermined amplitude condition may be delimited by lower and upper amplitudes limits (thresholds). The information may include digital data and may represent a frequency spectrum peak. The detected sound may be used to determine whether the closed container contains a pressure level within a predetermined range of pressure levels.

[0014] The predetermined spectral frequency and spectral amplitude conditions may define a good container region, and the determining steps may include comparing the frequency and the amplitude of a spectral frequency peak to the good container region. Containers may be rejected or accepted based on the results of the determining step. For instance, containers with associated frequency accepted. Containers with associated spectral frequency peaks that are outside a range of acceptable frequencies may be rejected as well as containers with associated spectral frequency peaks that are within a range of acceptable frequencies but which have amplitudes below a minimum amplitude threshold or above a maximum amplitude threshold. Rejected containers may contain a pressure level below a predetermined range of acceptable pressure levels.

[0015] Alternatively, the predetermined spectral frequency condition and the predetermined spectral amplitude condition may define a bad container region, and determining may include comparing the frequency and the amplitude of a spectral frequency peak to the bad container region. Examples of sound which may indicate a bad container region are sounds generated from a metal cap on a glass bottle and the metal surface of a beverage can. The bad container region is defined by a predetermined frequency condition and a predetermined amplitude condition. Containers with associated spectral frequency peaks that are within the bad container region may be rejected while containers with associated spectral frequency peaks that are outside the bad container region may be accepted.

[0016] The apparatus may include an acoustic transducer for measuring reactant sound produced by the vibration, and a controller electrically connected to the acoustic transducer, for detecting a frequency peak within the reactant sound and for comparing the frequency peak to a good or bad container region. The acoustic transducer may include a microphone. The controller may include a digital signal processor for receiving and performing a fast Fourier transform (FFT) on electrical signals from the acoustic transducer to provide the signal spectral characteristics. In a preferred form of apparatus, a rotary position (shaft) encoder provides the controller with the current speed of the manufacturing line. Using both the shaft encoder and a photobeam assembly, the

controller accurately locates the positions of containers as they pass through the inspection system and matches collected data to the positions of containers. Accurate matching improves the detection of defective cans. Additionally, with an accurate determination of a defective can's position, the controller may reliably cause a rejection station (see below) to remove the defective can from the manufacturing line. controller may reliably cause a rejection station (see below) to remove the defective can from the manufacturing line.

[0017] The apparatus of the invention may include a rejecting station for rejecting containers with associated spectral frequency peaks outside the good container, or within the bad container, region. The apparatus may also include a conveyor belt for carrying the containers through an inspection station.

[0018] The apparatus may also include an analyzer for deriving a frequency versus amplitude spectrum of the vibration, digital storage for holding the spectrum and data sufficient to analyze the internal pressure based on the spectrum, and a processor for generating the data. The processor may include means for energizing the aforementioned coil and controlling the analyzer to generate frequency versus amplitude spectra for vibrations of a series of test containers having different, known internal pressures, and means for deriving the data from the spectra.

[0019] The apparatus may also include storage for holding time domain data corresponding to the vibration, circuitry and associated software for deriving a frequency versus amplitude spectrum from the time domain data, and a display for showing a two-dimensional graphic image of the spectrum.

[0020] The present apparatus can provide rapid, accurate determinations of the internal pressure/vacuum of a variety of containers, including cans, pop top bottles, and vacuum packed foil bags. Improperly pressurized or vacuumed containers are detected because the amplitude of a frequency peak in the container's reactant sound is too high or too low when the frequency of the peak is within a selected frequency range.

[0021] As already indicated, a preferred form of the method allows dynamically changing the process control limits for judging internal pressure as a function of slowly varying changes in the upstream container filling process to optimize throughput without permitting the passage of reject containers. In this form of the method, at least one (and preferably both) of the lower limit and the upper limit defining the amplitude condition are reset in dependence upon the average value and the deviation resulting from the analysis of data from a plurality of containers as described above.

[0022] The average and the deviation may desirably be calculated as the average and standard deviation of a Gaussian or skew Gaussian distribution and the upper and lower limits may be set to the average plus or minus respectively a predetermined number of standard deviations, desirably not less than 3. The method may include the provision of an absolute lower limit and an absolute upper limit, and the resetting of the limits may be effected so that the lower limit is not set lower than the absolute lower limit, nor is the upper limit set higher than the absolute upper limit. The analysis may include checking that the amplitude data do conform to an assumed standard distribution and that, for example, there is not some abrupt break in the amplitude data part way through the sequence of containers tested which would indicate an abrupt change in the container filling conditions and thus a malfunction in the filling apparatus. Such checking may include deriving an average value and a deviation for a first subset (for example, the first half) of the plurality of containers, deriving an average value and a deviation for a second subset (for example, the second half) of the plurality of containers, where the second subset of containers passed through the container inspection station after the containers in the first subset, calculating the differences between the average values and the deviations for the two subsets, and rejecting the accumulated data if either of these differences exceeds a predetermined value (for example, if either difference exceeds twice that expected by standard statistical group methods). The method may also include the step of checking for modulation distortion in the data and compensating for such modulation distortion if present, as described above.

[0023] The structure, operation, and methodology of the methods and apparatus of the invention are further described in the following detailed description in connection with the drawings in which unique reference numerals have been used throughout for each part or feature and wherein:

Fig. 2 is a side view of the inspection station of Fig. 1 and an associated rejection station;

Fig. 3 is an end view of the inspection station of Fig. 1 and an associated controller;

Fig. 4 is a block diagram of the components of the controller of Fig. 3;

Figs. 5a-5c are frequency domain graphs of pop top bottle acoustic responses for different internal vacuums;

Fig. 6a is a perspective view of a pop top bottle;

Figs. 6b and 6c are cross-sectional side views of a pop top bottle lid;

Figs. 7a and 7b are frequency domain graphs of coffee brick acoustic responses for different internal vacuums;

Fig. 8 is a perspective view of a vacuum packed foil bag;

Fig. 9 is a diagrammatic graph illustrating the distribution of peak responses as a function of frequency for a population of containers in which signal modulating distortion is present;

Fig. 10 is a diagrammatic representation of an acoustic container time domain signal in which distorting modulation is present;

Fig. 11 is a diagrammatic representation of the signal of Fig. 10 in rectified form;

Fig. 12 is a diagrammatic representation of a low-pass filtered version of the modulation signal shown in Fig. 11;

Fig. 13 is a diagrammatic representation of the signal of Fig. 12 showing the period of the modulating signal; and

Fig. 14 is a diagrammatic representation of the splitting effect that the presence of a modulating component can have on the fundamental frequency response of a container.

[0024] Often, containers being filled and sealed in a manufacturing line are defective due to improper seals or contamination. An improper seal may prevent a container from maintaining a proper vacuum or pressure. Contamination may cause excessive pressure within the container due to outgassing produced by bacteria as the material spoils. To detect improperly pressurized/vacuumed containers, a pulsed magnetic field is imposed on a conductive surface of the container to cause the surface to vibrate, and the acoustic response (i.e., reactant sound) caused by the vibration is analyzed.

[0025] The purpose of the analysis is to identify a frequency peak within the reactant sound and determine whether the frequency of that peak falls within predetermined frequency and amplitude ranges of acceptability. Ordinarily, this is a straightforward procedure because the frequency spectrum has a readily identifiable peak occurring at an easily determined frequency. As will be seen, however, it is not uncommon for the spectrum to be corrupted by the presence of misleading information introduced into the acoustic signature by distorting modulations that can be present due to the complicated vibratory nature of containers or other components in the measurement system. When this happens, it is necessary to be able to detect the presence of distorting signal modulations before applying the usual procedures for predicting acceptable product. The demodulation method and apparatus of this invention provide the capability for detecting the presence of signal distortion and compensating for it in a manner to be described.

[0026] Certain containers, for example, pop top bottles and vacuum packed foil bags, may be improperly pressurized/vacuumed or improperly capped but still produce a reactant sound including a frequency peak within the predetermined frequency range. Analyzing the frequency of the frequency peak alone, therefore, may not allow for the detection of all defective containers.

[0027] The amplitude of a frequency peak corresponding to an improperly pressurized/vacuumed container is generally much lower than the amplitude of a frequency peak corresponding to a properly pressurized/vacuumed container. Similarly, the amplitude of a frequency peak corresponding to an improperly capped container is generally much higher than the amplitude of a frequency peak corresponding to a properly capped container. For example, beer bottles that are "double crowned" (i.e., capped twice) may produce a reactant sound including a frequency peak with a very large amplitude. To detect these defective containers, the amplitude of the frequency peak is compared to minimum and maximum amplitude thresholds and the container is rejected if the amplitude falls below the minimum amplitude threshold or exceeds the maximum amplitude threshold.

[0028] Referring to Figs. 1-3, an inspection system 8 includes a conveyor belt 10 that carries closed containers 12 through a transducer (or inspection) station 14 at approximately 3000 containers per minute. A rotary position (shaft) encoder 16 is connected to a drive shaft (not shown) of the conveyor belt and provides a controller 18 with an accurate measurement of the current speed of the conveyor belt. As a container 12 approaches the transducer station 14, a photobeam assembly 20 detects an edge 22 of the container 12 and sends a notification signal to the controller 18. Upon notification, the controller 18 uses the speed of the conveyor belt, the fixed distance, d1, between the photobeam assembly 20 and the transducer station 14, and the width, W1, of the container 12 to calculate the position of the container 12 with respect to the center C of the transducer station 14.

[0029] When the container is centered beneath the transducer station 14 , the controller 18 sends a signal to the transducer station 14 to cause the station to discharge a capacitor (not shown) through a coil 24. The coil is formed from a closely wound copper tape with Teflon (Registered Trade Mark) backing. The coil 24 is placed in a phenolic form and potted with an epoxy. The discharge produces a pulsed magnetic field which induces eddy currents on a conductive surface 26 of the container 12. The eddy currents generate a back electromagnetic force (the principle of the induction motor) causing the conductive surface 26 to vibrate. The vibration is influenced by the pressure/vacuum within the container 12 and the structure of the container 12 and its contents. A microphone 28, centered within coil 24 senses the acoustic energy (i.e., reactant sound) resulting from the vibration and converts it into a time-varying analog electrical signal which is sent to the controller 18.

[0030] The microphone 28 and coil 24 are positioned above a cone 30 to prevent them from being contaminated. Contamination may result from water droplets on container tops and from fluid used to clean the manufacturing line.

[0031] The photobeam assembly 20 may be a minibeam model No. SM312FMHS manufactured by Banner of Minneapolis, Minneapolis, United States of America. The shaft encoder 16 may be a model No. 62525400021 manufactured by Dynapar of Gurnee, Illinois, United States of America, and the microphone 28 may be a model No. 3140 manufactured by Gentex of Derry, New Hampshire, United States of America.

[0032] Referring to Fig. 4, a microphone input 36 within the controller 18 receives the output signal from the microphone 28 and passes the signal to a preamplifier 38.

An analog-to-digital (A/D) converter 40 digitizes the preamplifier's output every 45 microseconds, and a digital signal processor (DSP) 42 stores the A/D converter's digital output. The DSP performs fast Fourier transforms (FFT) on the samples to produce a power spectrum of approximately 512 bins (0-511), with the lower bin numbers corresponding to lower frequencies. The DSP then analyzes the power spectrum to detect for the presence of signal modulation and then determine the frequency and amplitude of the maximum frequency peak within the spectrum. The DSP and other programmable elements of the system are provided with suitable software code to perform the various tasks assigned to them. The sample window on the time domain signal is preferably adjusted to be long enough to capture the desired frequency resolution.

[0033] To determine the maximum frequency peak with no distortion present, the DSP 42 compares each bin value within the power spectrum to the next lower and higher bins in frequency. If both the lower and higher bins have values that are less than the value of the bin being considered, then the bin represents a peak. After finding a peak, if the DSP 42 finds another peak within the spectrum, it compares the amplitude of both peaks and stores the frequency and amplitude of the peak with the highest amplitude. Once the DSP 42 has checked the FFT value of each bin within the power spectrum, the frequency and amplitude of the peak with the highest amplitude is sent to a microprocessor 44 for further evaluation. If no peak is found, then the DSP sends an error code to the microprocessor.

[0034] If the frequency of the peak is within a predetermined acceptable frequency range and the amplitude of the peak is above a predetermined minimum amplitude and below a predetermined maximum amplitude, then the container 12 is determined to be properly pressurized/vacuumed and properly capped. For instance, referring to Figs. 5a-5c, frequency domain signals are shown for vacuum-packed pop top bottles containing, for example, fruit juice. The lid 46 (Figs. 6a-6c) of a pop top bottle 47 has a center portion that is cupped and flexible. When the bottle is properly filled and sealed, the curvature of the cup is concave 48 (Fig. 6c, i.e., in a down position) and the lid maintains a vacuum of approximately 15-30 inches Hg (50-100 kPa) within the bottle. Peak frequency 50 (Fig. 5A) at about bin 108 represents the resonant frequency of a properly filled pop top bottle.

[0035] The cupped lid of a pop top bottle generally produces approximately the same resonant frequency whether it is in the concave 48 (Fig. 6c, down) or convex 52 (Fig. 6b, up) position. For example, peak 54 (Fig. 5b) represents the resonant frequency of a pop top bottle that is improperly filled but contains a sufficient vacuum to maintain the curvature of the lid in a concave (down) position. The lid of this bottle produces a reactant sound having a frequency peak which is outside a predetermined frequency range 56 of acceptable frequencies. Peak 58 (Fig. 5c) represents the reactant sound of a pop top bottle that contains little or no pressure and, thus, the curvature of the lid is in a convex (up) position. In this position, the lid produces a reactant sound having a frequency peak which is within acceptable frequency range 56 and would be accepted if frequency were the only criterion.

[0036] To correctly reject both pop top bottles associated with peaks 54 and 58 while accepting the pop top bottle associated with peak 50, the microprocessor analyzes both the frequency and the amplitude of the lid's reactant sound. The bottle associated with peak 50 is accepted because peak 50 is within the predetermined acceptable frequency range 56, above a predetermined minimum amplitude threshold 60, and below a predetermined maximum amplitude threshold 62. The bottles associated with peaks 54 and 58 are rejected because peak 54 is outside acceptable frequency range 56 and peak 58 is below minimum amplitude threshold 60.

[0037] Referring to Figs. 7a and 7b, power spectrums are shown for vacuum-packed bricks 64 (Fig. 8, e.g., coffee grounds vacuum packed in a rectangular foil bag). The package containing the coffee grounds is flexible and when the package is properly filled and sealed, it provides a hard surface and maintains a vacuum of approximately 100 mbar. Maximum peak 66, at about bin 130, represents the resonant frequency of a properly filled coffee brick.

[0038] Because the package is flexible, it generally produces multiple frequency peaks 66, 68, and 70. Peaks 72, 74, and 76 represent the reactant sound of an improperly filled (i.e., soft) brick. The controller correctly rejects the brick associated with peaks 72, 74, and 76 and correctly accepts the brick associated with peaks 66, 68, and 70 again by analyzing both the frequency and amplitude of the maximum frequency peak of the package's reactant sound to determine whether the brick is properly filled. The brick associated with peaks 66, 68, and 70 is accepted because maximum peak 66 is both within a predetermined acceptable frequency range 78, above a predetermined maximum amplitude threshold 82. The brick associated with peaks 72, 74, and 76 is rejected because 72 is outside the acceptable frequency range and peaks 74 and 76, which are within the acceptable frequency range, are below the minimum amplitude threshold 80.

[0039] Improperly filled bricks generally resonate at lower frequencies, e.g., peak 72, than properly filled bricks, e.g., peak 66. Therefore, instead of determining which bricks are properly sealed by looking for a frequency response within a good brick (container) region 84, the controller can determine which bricks are bad by looking for a frequency peak within a bad brick (container) region 86 above a good brick (container) region 87. For example, within a lower predetermined frequency range 88, a properly filled brick will not produce a reactant sound that includes a threshold 90. Thus, the microprocessor can reject every brick that produces a reactant sound having a frequency peak that is above the minimum am-

plitude threshold 90 within the frequency range.

[0040] Referring back to Fig. 2, after determining that a container is defective, the controller sends a signal to a rejecter station 92 to cause the rejecter station to remove the defective container from the manufacturing line. The rejecter may be an actuator 94 including a position with a bumper (not shown) positioned next to the conveyor belt to push improperly sealed containers 96 off the conveyor. Properly sealed containers 98 remain on the conveyor. The piston timing is accurately determined as a specific number of shaft encoder pulses after the container leaves the photobeam. Because the encoder accurately measures the speed of the conveyor belt, rejecter errors due to changes in conveyor belt speed are minimized.

[0041] Referring again to Fig. 3, an operator may set the predetermined frequency range and the minimum and maximum amplitudes (i.e., set-up parameters) through a console 100 (Fig. 4) on controller 18. These values may be empirically determined by passing a series of properly and improperly pressurized/vacuumed containers through the inspection system and observing the resulting power spectrums corresponding to each container on a graphic display 102. The graphic display contains a plot of the power spectrum including the maximum peak's bin number and amplitude (dB). The set-up parameters may then be stored within the controller. After a variety of types of containers have been tested and their set-up parameters stored, operators may initialize the inspection system for each container type by selecting from a list of container types corresponding to previously stored set-up parameters.

[0042] It will be appreciated that the peak (resonant) frequency of properly filled container, such as that of the peak 50 shown in Fig. 5a, is subject to normal statistical variation, so that if measures this peak frequency for a large number of properly filled containers and prepares a histogram of the number of containers versus peak frequency, if no modulating distortion is present in the data, this histogram will normally resemble a Gaussian curve, as shown in the central portion of Fig. 9. However, when modulating distortion is present in a container's acoustic spectrum, the histogram is altered to provide a population distribution as shown in Fig. 9, containing two side lobes. These side lobes actually contain acceptable containers, but these acceptable container may be identified as rejects if the modulations are not accounted for. For example, if Fig. 9 were derived from the same containers as those used to produce Fig. 5a, the frequency difference between the central lobe of Fig. 9 and the left-hand lobe can easily be sufficient that many containers in the left-hand lobe might have their peak frequencies 50 (Fig. 5a) shifted so far towards lower frequencies that the peak would lie below the low peak cutoff shown in that Figure, and consequently the containers would be rejected as failing to satisfy the spectral frequency condition.

[0043] When the reactant acoustic signal contains modulating distortion, the distortion must first be detected and, if found, the modulating distortion may be removed from the spectrum or the fact of its presence used in interpreting the power spectrum so that the modulating distortion is compensated. The procedure for detection and removal or compensation of the modulating distortion should be applied before the usual methodology for testing amplitude and frequency components of the signal discussed above.

[0044] Determining if modulating distortion is present in a signal may be done in either the time domain or the frequency domain. While the frequency domain approach is preferred in practice, the time domain approach will first be described to illustrate the nature of the problem.

[0045] If done in the time domain, one preferred method can be as follows. Referring now to Fig. 10 there is shown an acoustic signal in the time domain that contains distorting modulation. The method for dealing with this modulation is to first rectify the signal of Fig. 10 so that it appears as in Fig. 11. The rectified signal of Fig. 11 may be processed by applying a lowpass filter to generate the time varying signal of the modulation as shown in Fig. 12, although this step is not essential. The signal of Fig. 12 is then checked for any periodic waveforms. This is done by checking the modulation waveform for the existence of minima. A possible modulation frequency (1e) is then determined by the separation of the minima in the time domain as indicated in Fig. 13 to the corresponding frequency. This possible modulation frequency is used to check the frequency spectrum as shown in Fig. 14 for any possible frequency peaks (1g) that are separated by the modulation frequency (1e). If the modulation is present in the frequency spectrum of Fig. 14 as indicated by two peaks (1g) separated by the modulation frequency(1e), the modulation distortion can be compensated for by replacing the two frequency peaks (1g) with a single peak lying at the actual undistorted frequency (1i) half way between the two frequency peaks. (Note that in practice it may not be possible to place the single peak exactly half way between the two frequency peaks; Figures 9-14 essentially assume a continuous variation in frequency, whereas, as discussed above with reference to Figs. 5a, 5b, 5c, 7a and 7b, in practice the frequency spectrum is analyzed in a finite number of bins. If, for example , in practice the two peaks in Fig. 14 were at bin 100 and bin 111, one would need to replace them with a single peak at either bin 105 or bin 106. However, provided the single peak is placed substantially at the frequency half way between the two peaks, any minor deviation due to the finite number of bins does not significantly affect the results.) Desirably, the amplitude of the single peak is set equal to that of the larger of the two original peaks. Because a power spectrum is being used, it is permissible to take the larger of the two peaks since the difference between the two peaks in dB level is acceptably small compared with the differences in level at which rejection occurs.

[0046] Alternatively, and preferably, in testing for the presence of modulating distortion, one can proceed directly to the frequency power spectrum of Fig 14 and analyze it for the presence of two peaks of substantially equal amplitude separated by a frequency difference no greater more than a predetermined amount. If this condition is satisfied, that is, if the peaks fall within the predetermined frequency interval, modulating distortion is judged to be present, and the pair of peaks is replaced by a single peak in the manner previously described, this single peak having a frequency half way between frequencies of the pair of peaks occur, and an amplitude equal to that of the larger of the pair of peaks. The frequency and amplitude of this single new peak are then used as before to determine if the container response falls within the desired frequency range and within the desired amplitude range.

[0047] As already discussed, another aspect of the invention provides for automatic adjustment (resetting) of acceptable amplitude limits by assessing contemporaneous process capability and setting floating amplitude limits to optimize acceptable product. Since the upstream process for filling containers changes slowly in comparison to catastrophic failures, one can set floating amplitude limits so long as they do not exceed predetermined absolute upper and lower limits considered to represent failure levels. This adjustment or resetting is lower limits considered to represent failure levels. This adjustment or resetting is done by sampling a sequence of containers judged to be acceptable by the frequency/amplitude analysis already described and determining the distribution of peak amplitudes over some time interval. A sample interval corresponding to 128 containers has been found acceptable for this purpose. Here, the distribution of amplitudes is monitored (typically a normal distribution), an average and a deviation for this distribution is calculated and the upper and lower limits are reset to the average plus and minus respectively a predetermined number of deviations; in some cases, it may be desirable to reset only one of the upper and lower limits. Typically, the 3F (i.e., three times the standard deviation) limits for the 128 containers are used to automatically update the upper and lower limits on amplitude for the next 128 containers, although other multiples of F-limits may be used. In this way, the amplitude limits of acceptability can vary in accordance with slowly varying process conditions with the result that less product is rejected as the process slowly changes. However, as already indicated, to guard against the process dramatically changing (which probably indicates a malfunction in the filling apparatus), this screening technique can be provided with safeguards in the form of commands to ignore the adjustment of the floating point values and a signal that the process is out of control. For example, the process may include analysis to check that the amplitude data do conform to an assumed standard distribution; one possible technique for such analysis is to calculate an average and a deviation for two subsets of containers, for example the first and second halves of the 128 containers, calculate the differences two the two averages and the two deviations and reject the data for all 128 containers (and preferably generate an alarm) if either of these differences exceeds a predetermined value. Appropriate methods for setting this predetermined value will be apparent to those skilled in statistical analysis.

Claims

1. A method comprising:

inducing vibration in a surface of a closed container;
detecting sound resulting from the vibration;
deriving information representing the detected sound;
determining whether a frequency component of the information corresponds to a predetermined spectral frequency condition; and
determining whether an amplitude component of the information corresponds to a predetermined spectral amplitude condition,
characterized by testing the original information representing the detected sound to determine whether a modulating distortion is present therein, and if so compensating for the effects of the modulating distortion, thereby producing demodulated information;
and further **characterized in that** the determination, of whether the frequency component of the information corresponds to the predetermined spectral frequency condition, is carried out on the original information, if no modulating distortion has been found therein, but is carried out on the demodulated information, if modulating distortion has been found in the original information, and
the determination, of whether the amplitude component of the information corresponds to the predetermined spectral amplitude condition, is carried out on the original information, if no modulating distortion has been found therein, but is carried out on the demodulated information, if modulating distortion has been found in the original information.

2. A method according to claim 1 **characterized in that** the testing of the original information is effected by:

rectifying the original information to produce rectified information;
testing the rectified information for the presence of periodic minima, and if periodic minima are detected, measuring the period between successive minima, and converting this period to a possible modulation frequency;

deriving a frequency spectrum of the original information;
testing the frequency spectrum for the presence of a pair of peaks separated by a frequency difference substantially equal to the possible modulation frequency.

3. A method according to claim 2 **characterized in that** the rectified information is lowpass filtered before being tested for the presence of periodic minima.

4. A method according to claim 1 **characterized in that** the testing of the original information is effected by:

deriving a frequency spectrum of the original information;
testing the frequency spectrum for the presence of a pair of peaks of substantially equal amplitude separated by a frequency difference less than a predetermined value.

5. A method according to any one of claims 2 to 4 **characterized in that** the compensating for the effects of the modulating distortion is effected by replacing the pair of peaks in the frequency spectrum with a single peak lying substantially at the frequency halfway between the pair of peaks.

6. A method according to claim 5 **characterized in that** the amplitude of the single peak is made substantially equal to the larger of the amplitudes of the pair of peaks.

7. A method according to any one of the preceding claims **characterized in that** the surface is at least partially conductive and the vibration is induced by imposing a magnetic field on the surface.

8. A method according to any one of the preceding claims **characterized in that** it is carried out on a manufacturing line, in which closed containers are passed through a container inspection system, and the steps of inducing vibration in a surface of each of the closed containers and detecting sound resulting from the vibration are carried out at the container inspection station.

9. A method according to claim 8 **characterized by** rejecting containers for which the information used in the determination shows spectral frequency peaks that are outside a range of acceptable frequencies, and also rejecting containers for which this information shows spectral frequency peaks that are within a range of acceptable frequencies but which have amplitudes below a minimum amplitude threshold or above a maximum amplitude threshold.

10. A method according to claim 1 wherein a plurality of closed containers are subjected to the process and the determination of whether the amplitude component of the information corresponds to the predetermined spectral amplitude condition is made by comparing the amplitude component to a range of acceptable values delimited by a lower limit and an upper limit;
the method further comprising accumulating, from a plurality of containers inspected and judged to be satisfactory by satisfying the predetermined spectral frequency condition and the predetermined spectral amplitude condition, amplitude data for the amplitude components of the containers;
analyzing the amplitude data to derive an average value and a deviation therefrom; and
resetting at least one of the lower limit and the upper limit in dependence upon the average value and the deviation.

11. A method according to claim 10 **characterized in that** both the lower limit and the upper limit are reset in dependence upon the average value and the deviation.

12. A method according to claim 11 **characterized in that** the average and the deviation are calculated as the average and standard deviation of a Gaussian or skew Gaussian distribution and the upper and lower limits are set to the average plus and minus respectively a predetermined number of standard deviations.

13. A method according to any one of claims 10 to 12 **characterized in that** there are predetermined an absolute lower limit and an absolute upper limit, and the resetting is effected so that the lower limit is not set lower than the absolute lower limit, nor is the upper limit set higher than the absolute upper limit.

14. A method according to any one of claims 10 to 13 **characterized in that** the analysis includes checking that the amplitude data do conform to an assumed standard distribution.

15. A method according to claim 14 **characterized in that** the checking includes:

deriving an average value and a deviation for a first subset of the plurality of containers;
deriving an average value and a deviation for a second subset of the plurality of containers, where the second subset of containers were inspected after the containers in the first subset;
calculating the differences between the average values and the deviations for the two subsets; and
rejecting the accumulated data if either of these differences exceeds a predetermined value.

16. Apparatus for analyzing the internal pressure of a closed container, the apparatus comprising:

a vibrator for inducing vibration in a surface of the closed container;
a sound detector for detecting sound resulting from the vibration;
information derivation means for deriving information representing the detected sound; and
a data processor arranged to:

(a) determine whether a frequency component of the information corresponds to a predetermined spectral frequency condition;
(b) determine whether an amplitude component of the information corresponds to a predetermined spectral amplitude condition; and
(c) produce a first output signal if the frequency component and the amplitude component correspond to the predetermined spectral frequency and amplitude condition respectively, and a second output signal if the frequency component fails to satisfy the predetermined spectral frequency condition or the amplitude component fails to satisfy the predetermined spectral amplitude condition, **characterized in that** the data processor is also arranged to test the original information from the information derivation means to determine whether a modulating distortion is present in the original information, and if so to compensate for the effects of the modulating distortion, thereby producing demodulated information;

and further **characterized in that** the data processor is arranged to carry out steps (b) and (c) on the original information, if no modulating distortion has been found therein, but to carry out steps (b) and (c) on the demodulated information, if modulating distortion has been found in the original information.

17. Apparatus according to claim 16 **characterized in that** the data processor is arranged to test the original information by a method according to any one of claims 2 to 6.

18. Apparatus according to claim 16 wherein the data processor arranged to determine whether the amplitude component of the information corresponds to the predetermined spectral amplitude condition by comparing the amplitude component to a range of acceptable values delimited by a lower limit and an upper limit,
the data processor also being arranged to accumulate, from a plurality of containers judged to be satisfactory by satisfying the predetermined spectral frequency condition and the predetermined spectral amplitude condition, amplitude data for the amplitude components of the containers, to analyze this amplitude data to derive an average value and a deviation therefrom, and to reset at least one of the lower limit and the upper limit in dependence upon the average value and the deviation.

19. Apparatus according to claim 18 **characterized in that** the data processor is arranged to reset at least one of the lower limit and the upper limit in the manner specified in any one of claims 11 to 15.

Patentansprüche

1. Eine Methode, welche folgendes umfasst:

induzierende Schwingung in der Oberfläche eines geschlossenen Behälters;
Geräuscherkennung auf Grund der Schwingung;
Herleitung von Informationen, welche das erkannte Geräusch abbilden;
Bestimmung, ob eine Frequenzkomponente der Informationen einem vorgegebenen spektralen Frequenzzustand entspricht; und
Bestimmung, ob eine Amplitudenkomponente der Informationen einem vorgegebenen spektralen Amplitudenzustand entspricht,
dadurch gekennzeichnet, dass durch eine Prüfung der ursprünglichen das erkannte Geräusch abbildenden Informationen bestimmt wird, ob eine modulierende Verzerrung dort vorliegt, und, sollte dies der Fall sein, die Bewirkung einer Kompensierung für die Auswirkungen der modulierenden Verzerrung und somit einer Erzeugung demodulierter Informationen;
und weiterhin **dadurch gekennzeichnet, dass** die Bestimmung, ob die Frequenzkomponente der Informationen dem vorgegebenen spektralen Frequenzzustand entspricht, gemäß der ursprünglichen Informationen ausgeführt wird, falls keine Modulierungsverzerrungen dort angetroffen wurden, jedoch gemäß der demodulierten Informationen ausgeführt wird, sollte eine modulierende Verzerrung in den ursprünglichen Informationen angetroffen worden sein, und
die Bestimmung, ob die Amplitudenkomponente der Informationen dem vorgegebenen spektralen Amplitudenzustand entspricht, gemäß den ursprünglichen Informationen ausgeführt wird, sollte dort keine modulierende Verzerrung angetroffen worden sein; sie jedoch gemäß der demodulierten Informationen ausgeführt wird, sollte eine modulierende Verzerrung in den ursprünglichen Informationen angetroffen worden

sein.

2. Eine Methode gemäß Anspruch 1, **dadurch gekennzeichnet, dass** die Prüfung der ursprünglichen Informationen mittels des Folgenden ausgeführt wird:

   Richtigstellung der ursprünglichen Informationen zur Erzeugung der richtig gestellten Informationen;
   Prüfung der richtig gestellten Informationen auf das Vorhandensein periodischer Minima, und, sollten diese erkannt worden sein, die Messung der Zeitdauer zwischen den aufeinander folgenden Minima und Konvertierung dieses Zeitabschnitts in eine eventuelle Modulationsfrequenz;
   Ableitung eines Frequenzspektrums von den ursprünglichen Informationen;
   Prüfung des Frequenzspektrums auf das Vorhandensein eines Paars von Höchstwerten, die von einer Frequenzdifferenz getrennt sind, welche im Wesentlichen gleich der möglichen Modulationsfrequenz ist.

3. Eine Methode gemäß Anspruch 2, **dadurch gekennzeichnet, dass** die richtig gestellten Informationen vor der Prüfung auf ein Vorhandensein periodischer Minima durch einen Tiefpassfilter geleitet werden.

4. Eine Methode gemäß Anspruch 1, **dadurch gekennzeichnet, dass** die Prüfung der ursprünglichen Informationen wie folgt durchgeführt wird:

   Ableitung eines Frequenzspektrums von den ursprünglichen Informationen;
   Prüfung des Frequenzspektrums auf das Vorhandensein eines Paares von im Wesentlichen gleicher Amplitude, die von einer Frequenzdifferenz getrennt wird, welche weniger als der vorgegebene Wert ist.

5. Eine Methode gemäß einer der Ansprüche 2 bis 4, **dadurch gekennzeichnet, dass** die Kompensierung hinsichtlich der Auswirkungen der modulierenden Verzerrung durch ein Austauschen des Paars von Höchstwerten im Frequenzspektrum mit einem einzelnen Höchstwert ausgeführt wird, dessen Frequenz im Wesentlichen auf halbem Wege zwischen dem Paar der Höchstwerte liegt.

6. Eine Methode gemäß Anspruch 5, **dadurch gekennzeichnet, dass** die Amplitude des einzelnen Höchstwerts im Wesentlichen gleich der größeren der Amplituden des Paars der Höchstwerte sind.

7. Eine Methode gemäß einer der vorangehenden Ansprüche, **dadurch gekennzeichnet**, das die Oberfläche zumindest teilweise leitfähig ist, und dass die Schwingung durch Auferlegung eines Magnetfelds auf die Oberfläche bedingt ist.

8. Eine Methode gemäß einer der vorangehenden Ansprüche, **dadurch gekennzeichnet, dass** sie auf einer Produktionsanlage ausgeführt wird, auf dem geschlossene Behälter durch ein Prüfsystem für Behälter geführt werden, und die Schritte zur Induzierung einer Schwingung in der Oberfläche der jeweiligen geschlossenen Behälter und die Erkennung von Geräuschen auf Grund der Schwingung auf der Inspektionstelle für Behälter ausgeführt werden.

9. Eine Methode gemäß Anspruch 8, **dadurch gekennzeichnet, dass** durch eine Aussonderung von Behältern für die die in der Bestimmung verwendeten Informationen spektrale Frequenzhöhepunkte anzeigen, welche außerhalb des Bereichs annehmbarer Frequenzen liegen, sowie auch die Aussonderung von Behältern, für die diese Informationen spektrale Frequenzhöchstwerte anzeigen, welche innerhalb eines Bereichs akzeptabler Frequenzen liegen, welche jedoch Amplituden unter einem Schwellenmindestwert oder über einem Höchstschwellenwert für Amplituden haben.

10. Eine Methode gemäß Anspruch 1, in dem eine Vielzahl geschlossener Behälter dem Vorgang unterzogen werden, und
    die Bestimmung, ob die Amplitudenkomponente der Informationen dem vorgegebenen spektralen Amplitudenzustand entspricht, durch einen Vergleich der Amplitudenkomponente mit einer Reihe akzeptabler Werte abgegrenzter Werte und einer Höchstgrenze ausgeführt wird;
    die Methode umfasst weiterhin die Anhäufung von Amplitudenwerten für die Amplitudenkomponenten der Behälter von einer Vielzahl an Behältern, die inspiziert und als zufriedenstellend beurteilt wurden, indem sie dem vorgegebenen spektralen Frequenzzustand und dem vorgegebenen spektralen Amplitudenzustand Genüge leisten;
    Analyse der Amplitudendaten zur Ableitung einer Durchschnittswerts und einer diesbezüglichen Abweichung; und
    Rückstellung von mindestens einer der unteren und der oberen Grenzwerte in Anlehnung an den Durchschnittswert und die Abweichung.

11. Eine Methode gemäß Anspruch 10, **dadurch gekennzeichnet, dass** der obere und untere Grenzwert in Anlehnung an den Durchschnittswert und die Abweichung rückgesetzt werden.

12. Eine Methode gemäß Anspruch 11, **dadurch gekennzeichnet, dass** der Durchschnitt und die Ab-

weichung einer Gauß'chen oder verzerrten Gauß'schen Verteilung und der oberen und unteren Grenzwerte auf das jeweils durchschnittliche Plus oder Minus einer vorgegebenen Anzahl an Standardabweichungen eingestellt sind.

13. Eine Methode gemäß einer der Ansprüche 10 bis 12, **dadurch gekennzeichnet, dass** eine absolute Untergrenze und eine absolute Obergrenze vorgegeben sind, und dass die Rückstellung so ausgeführt wird, dass die Untergrenze nicht niedriger als die absolute Untergrenze eingestellt wird noch dass die Obergrenze nicht höher als die absolute Obergrenze eingestellt wird.

14. Eine Methode gemäß einer der Ansprüche 10 bis 13, **dadurch gekennzeichnet, dass** die Analyse die Prüfung umfasst, dass die Amplitudendaten den vorausgesetzten angenommenen Standardvertrieb entsprechen.

15. Eine Methode gemäß Anspruch 14, **dadurch gekennzeichnet, dass** die Prüfung Folgendes umfasst:

Ableitung eines Durchschnittswerts und einer Abweichung für eine erste Teilmenge der Vielzahl an Behältern;
Ableitung eines Durchschnittswerts und einer Abweichung für einen zweiten Teilsatz an Behältern, wobei die zweite Untermenge an Behältern nach den Behältern des ersten Teilsatzes inspiziert wurden;
Errechnung des Unterschieds zwischen den Durchschnittswerten und den Abweichungen für die beiden Teilsätze; und
Aussonderung der gesammelten Daten, falls eine dieser Abweichungen einen vorgegebenen Wert überschreitet.

16. Eine Vorrichtung zur Analyse des internen Drucks eines geschlossenen Behälters, wobei die Vorrichtung Folgendes umfasst:

einen Vibrator zur Erzeugung einer Schwingung in der Oberfläche eines geschlossenen Behälters;
einen Geräuschmelder zur Erkennung von sich auf Grund der Schwingung ergebenden Geräuschen;
Vorrichtungen zur Ableitung von Informationen, um Informationen abzuleiten, welche das erkannte Geräusch darstellen; und
ein Datenprozessor, der angeordnet ist, um:

(a) festzustellen, ob eine Frequenzkomponente der Informationen einem vorgegebenen spektralen Frequenzzustand entspricht;
(b) festzustellen, ob eine Amplitudenkomponente der Informationen einem vorgegebenen spektralen Amplitudenzustand entspricht;
(c) ein erstes Ausgabesignal zu erzeugen, sollte die Frequenzkomponente und die Amplitudenkomponente jeweils einem vorgegebenen spektralen Frequenz und Amplitudenzustand entsprechen, sowie auch ein zweites Ausgabesignal, sollte die Frequenzkomponente nicht erfolgreich dabei sein, um den vorgegebenen spektralen Frequenzzustand zu erfüllen, oder sollte die Amplitudenkomponente es versäumen, die vorgegebene spektrale Amplitudenzustand zu erfüllen,

dadurch gekennzeichnet, dass der Datenprozessor des Weiteren so ausgeführt wurde, dass er die ursprünglichen Informationen von der Herleitungsvorrichtung für Informationen prüfen kann, um festzustellen, ob eine modulierende Verzerrung in den ursprünglichen Informationen vorliegt und in einem solchen Fall die Auswirkungen der modulierenden Verzerrung ausgleicht und somit demodulierende Informationen erzeugt;
und weiterhin **dadurch gekennzeichnet, dass** der Datenprozessor so ausgeführt ist, dass er Schritte (b) und (c) der ursprünglichen Informationen ausführt, sollte keine Modulationsverzerrung dort angetroffen worden sein, jedoch Schritte (b) und (c) gemäß den demodulierten Informationen ausführt, sollte eine modulierende Verzerrung in den ursprünglichen Informationen angetroffen worden sein.

17. Eine Vorrichtung gemäß Anspruch 16, **dadurch gekennzeichnet, dass** der Datenprozessor so angeordnet ist, dass der die ursprünglichen Informationen mittels einer Methode gemäß einer der Ansprüche 2 bis 6 prüft.

18. Eine Vorrichtung gemäß Anspruch 16, wobei der Datenprozessor so angeordnet ist, dass er bestimmen kann, ob die Amplitudenkomponente der Informationen dem vorgegebenen spektralen Amplitudenzustand entspricht, indem die Amplitudenkomponente mit einem Bereich annehmbarer Werte verglichen wird, welcher durch eine Untergrenze und eine Obergrenze abgegrenzt ist,
wobei der Datenprozessor des Weiteren so angeordnet ist, dass er von einer Vielzahl an Behältern, die als zufriedenstellend beurteilt wurden, da sie die vorgegebene spektrale Frequenzzustand und den vorgegebenen spektralen Amplitudenzustand erfüllen, Amplitudendaten für die Amplitudenkomponen-

ten der Behälter zur Analyse dieser Amplitudendaten ansammelt, um einen Durchschnittswert und eine diesbezügliche Ableitung abzuleiten, und mindestens eine der Obergrenze und der Untergrenze rückzustellen und zwar in Anlehnung an den Durchschnittswert und die Ableitung.

19. Vorrichtung gemäß Anspruch 18, **dadurch gekennzeichnet, dass** der Datenprozessor so angeordnet ist, dass er mindestens eine der Untergrenzen und Obergrenzen in der Art und Weise rückstellt, wie in einem der Ansprüche 11 bis 15 angegeben.

Revendications

1. Une méthode se résumant à :

induire des vibrations dans une surface d'un conteneur fermé ;
détecter le son résultant de la vibration ;
dériver de l'information représentant le son détecté ;
déterminer si une composante de fréquence de l'information correspond à une condition de fréquence spectrale prédéterminée ; et
déterminer si une composante d'amplitude de l'information correspond à une condition d'amplitude spectrale prédéterminée,
caractérisée en évaluant l'information originale représentant le son détecté pour déterminer si une distorsion de modulation est présente et, dans ce cas, en compensant les effets de la distorsion de modulation, produisant ainsi l'information démodulée ;
et **caractérisée** d'autre part en ce que la détermination, à savoir identifier si la composante de fréquence de l'information correspond à la condition de fréquence spectrale prédéterminée, est effectuée sur l'information originale, si aucune distorsion de modulation n'a été trouvée dans cette information, mais est effectuée sur l'information démodulée, si une distorsion de modulation a été trouvée dans l'information originale, et
la détermination, à savoir identifier si l'amplitude de l'information correspond à la condition d'amplitude spectrale prédéterminée, est effectuée sur l'information originale, si aucune distorsion de modulation n'a été trouvée dans cette information, mais est effectuée sur l'information démodulée, si une distorsion de modulation a été trouvée dans l'information originale.

2. Une méthode conformément à la revendication 1 **caractérisée en ce que** la vérification de l'information originale est effectuée :

en redressant l'information originale pour produire une information redressée ;
en évaluant l'information redressée en recherchant la présence de minima périodiques,et si des minima périodiques sont détectés, en mesurant la période entre les minima successifs et en convertissant cette période en fréquence de modulation possible ;
en dérivant un spectre de fréquence de l'information originale ;
en évaluant le spectre de fréquence en recherchant la présence d'une paire de crêtes séparées par une différence de fréquence substantiellement égale à la fréquence de modulation possible.

3. Une méthode conformément à la revendication 2 **caractérisée en ce que** l'information redressée est filtrée sur un filtre passe-bas avant d'être évaluée pour la présence de minima périodiques.

4. Une méthode conformément à la revendication 1 **caractérisée en ce que** la vérification de l'information originale est effectuée en :

dérivant un spectre de fréquence de l'information originale ;
évaluant le spectre de fréquence en recherchant la présence d'une paire de crêtes d'amplitudes substantiellement égales séparées par une différence de fréquence inférieure à une valeur prédéterminée.

5. Une méthode conformément à l'une quelconque des revendications 2 à 4 **caractérisée en ce que** la compensation des effets de la distorsion de modulation est effectuée en remplaçant la paire de crêtes dans le spectre de fréquence par une seule crête placée substantiellement à la fréquence médiane entre la paire de crêtes.

6. Une méthode conformément à la revendication 5 **caractérisée en ce que** l'amplitude de la crête unique est substantiellement égale à la plus grande des amplitudes de la paire de crêtes.

7. Une méthode conformément à l'une quelconque des revendications précédentes **caractérisée en ce que** la surface est au moins partiellement conductrice et la vibration est induite en imposant un champ magnétique sur la surface.

8. Une méthode conformément à l'une quelconque des revendications précédentes **caractérisée en ce qu'**elle est effectuée sur une ligne de fabrication, dans laquelle des conteneurs fermés passent au travers d'un système d'inspection de conteneur, et les étapes d'induction de vibration dans une surface de

chacun des conteneurs fermés et de détection de son résultant de la vibration sont effectuées au poste d'inspection du conteneur.

9. Une méthode conformément à la revendication 8 **caractérisée en** rejetant les conteneurs pour lesquels l'information utilisée dans la détermination montre des crêtes de fréquence spectrale en dehors d'une plage de fréquences acceptables ainsi qu'en rejetant les conteneurs pour lesquels cette information montre des crêtes de fréquence spectrale qui sont dans une plage de fréquences acceptables mais qui ont des amplitudes inférieures à un seuil d'amplitude minimum ou supérieures à un seuil d'amplitude maximum.

10. Une méthode conformément à la revendication 1 dans laquelle une pluralité de conteneurs fermés sont soumis au processus et
la détermination, à savoir identifier si la composante d'amplitude de l'information correspond à la condition d'amplitude spectrale prédéterminée, est faite en comparant la composante d'amplitude à une plage de valeurs acceptables délimitées par une limite inférieure et une limite supérieure ;
la méthode comprenant également l'accumulation, à partir d'une pluralité de conteneurs inspectés et considérés satisfaisants en répondant à la condition de fréquence spectrale prédéterminée et à la condition d'amplitude spectrale prédéterminée, des données d'amplitude pour les composantes d'amplitude des conteneurs ;
l'analyse des données d'amplitude pour dériver une valeur moyenne et un écart-type à partir de ces valeurs ; et
la réinitialisation d'au moins la limite inférieure ou la limite supérieure en fonction de la valeur moyenne et de l'écart-type.

11. Une méthode conformément à la revendication 10 **caractérisée en ce que** la limite inférieure et la limite supérieure sont toutes deux réinitialisées en fonction de la valeur moyenne et de l'écart-type.

12. Une méthode conformément à la revendication 11 **caractérisée en ce que** la moyenne et l'écart-type sont calculés comme la moyenne et l'écart-type d'une distribution normale ou normale asymétrique et les limites supérieure et inférieure sont réglées à la moyenne plus ou moins respectivement un nombre prédéterminé d'écarts-types.

13. Une méthode conformément à une quelconque des revendications 10 à 12 **caractérisée en qu'**une limite inférieure absolue et une limite supérieure absolue sont prédéterminées et la réinitialisation est effectuée de manière à ce que la limite inférieure n'est pas définie inférieure à la limite inférieure absolue et la limite supérieure n'est pas définie supérieure à la limite supérieure absolue.

14. Une méthode conformément à l'une quelconque des revendications 10 à 13 **caractérisée en ce que** l'analyse comprend la vérification que les données d'amplitude sont conformes à une distribution standard supposée.

15. Une méthode conformément à la revendication 14 **caractérisée en ce que** la vérification comprend :

la dérivation d'une valeur moyenne et d'un écart-type pour un premier sous-ensemble de la pluralité des conteneurs ;
la dérivation d'une valeur moyenne et d'un écart-type pour un second sous-ensemble de la pluralité des conteneurs, où le second sous-ensemble de conteneurs a été inspecté après les conteneurs du premier sous-ensemble ;
le calcul des différences entre les valeurs moyennes et les écarts-types pour les deux sous-ensembles ; et
le rejet des données accumulées si une de ces différences est supérieure à une valeur prédéterminée.

16. Appareil pour analyser la pression interne d'un conteneur fermé, l'appareil étant composé :

d'un vibrateur induisant des vibrations dans une surface du conteneur fermé ;
d'un détecteur de son pour détecter les sons résultant de la vibration ;
de moyens de dérivation d'information pour dériver l'information représentant le son détecté ; et
d'un processeur de données configuré pour :

(a) déterminer si une composante de fréquence de l'information correspond à une condition de fréquence spectrale prédéterminée ;
(b) déterminer si une composante d'amplitude de l'information correspond à une condition d'amplitude spectrale prédéterminée ; et
(c) produire un premier signal de sortie si la composante de fréquence et la composante d'amplitude correspondent respectivement à la condition prédéterminée de fréquence spectrale et d'amplitude , et un second signal de sortie si la composante de la fréquence ne satisfait pas la condition de fréquence spectrale prédéterminée ou si la composante d'amplitude ne satisfait pas la condition d'amplitude spectrale prédéterminée,

caractérisé en ce que le processeur de données est aussi configuré pour évaluer l'information originale à partir des moyens de dérivation de l'information afin de déterminer si une distorsion de modulation est présente dans l'information originale et, le cas échéant, pour compenser les effets de la distorsion de modulation, produisant ainsi l'information démodulée ;

et autrement **caractérisé en ce que** le processeur de données est configuré pour effectuer les étapes (b) et (c) sur l'information originale, si aucune information de distorsion de modulation n'a été trouvée dans cette information, mais pour effectuer les étapes (b) et (c) sur l'information démodulée, si une distorsion de modulation a été trouvée dans l'information originale.

17. Appareil conformément à la revendication 16 **caractérisé en ce que** le processeur de données est configuré de manière à évaluer l'information d'origine par une méthode conformément à une quelconque des revendications 2 à 6.

18. Appareil conformément à la revendication 16 où le processeur de données configuré pour déterminer si la composante d'amplitude de l'information correspond à la condition d'amplitude spectrale prédéterminée en comparant la composante d'amplitude à une plage de valeurs acceptables délimitée par une limite inférieure et une limite supérieure,
le processeur de données étant aussi configuré de manière à accumuler, à partir d'une pluralité de conteneurs considérés satisfaisants en remplissant la condition de fréquence spectrale prédéterminée et la condition d'amplitude spectrale prédéterminée, les données d'amplitude pour les composantes d'amplitude des conteneurs, afin d'analyser ces données d'amplitude pour dériver une valeur moyenne et un écart-type à partir de celles-ci, et pour réinitialiser au moins la limite supérieure ou la limite inférieure en fonction de la valeur moyenne et de l'écart-type.

19. Appareil conformément à la revendication 18 **caractérisé en ce que** le processeur de données est configuré de manière à réinitialiser au moins la limite inférieure ou la limite supérieure de la manière spécifiée dans une quelconque des revendications 11 à 15.

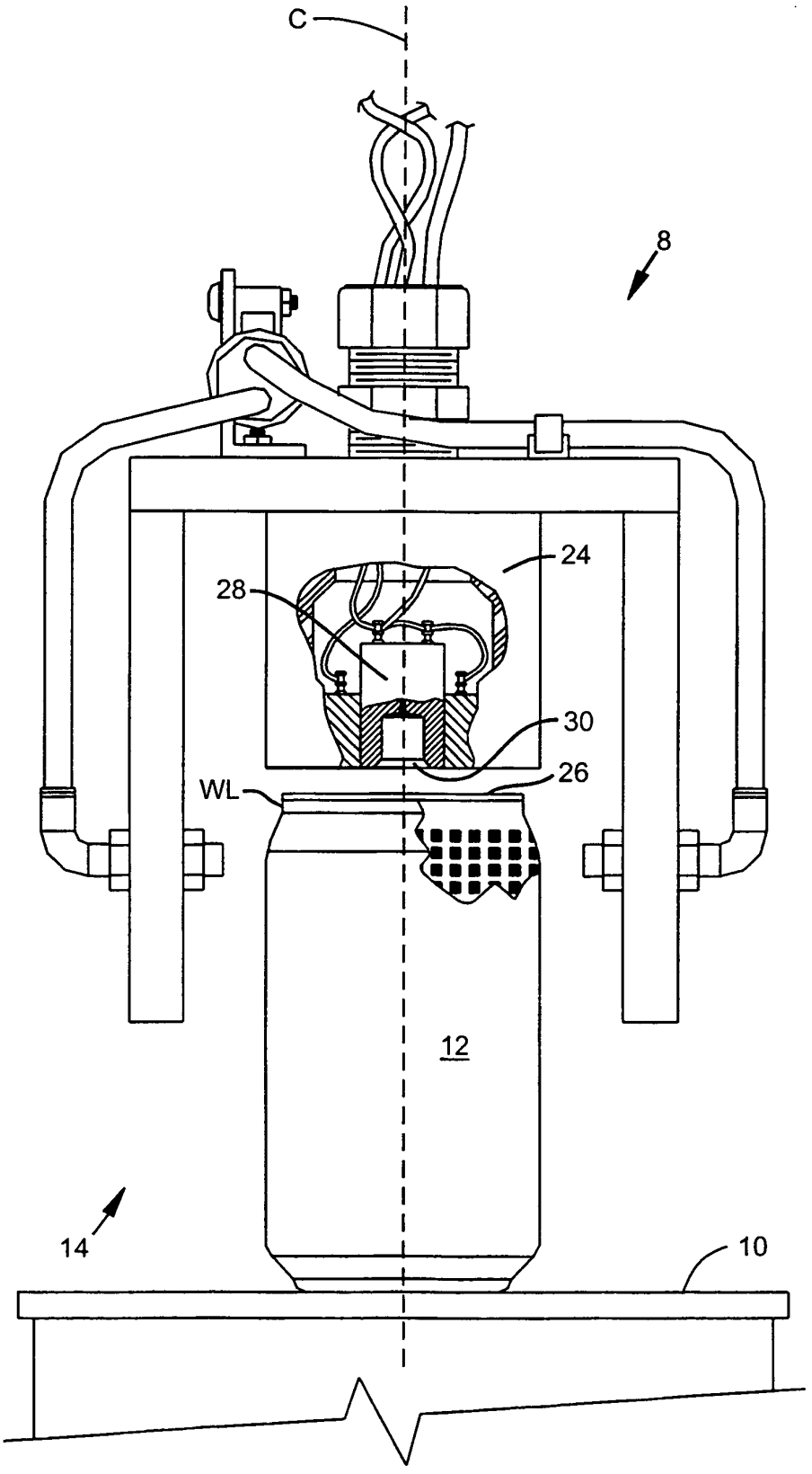


FIG. 1

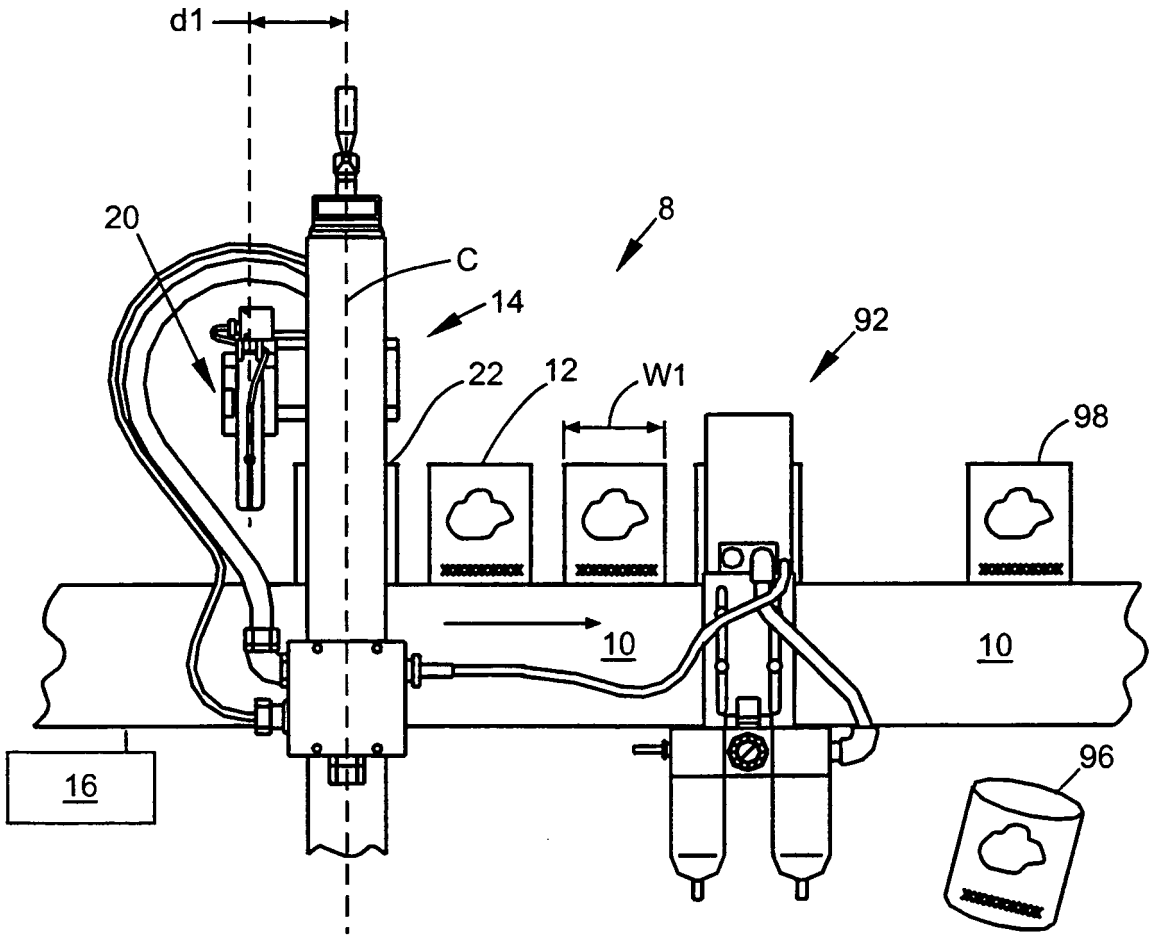


FIG. 2

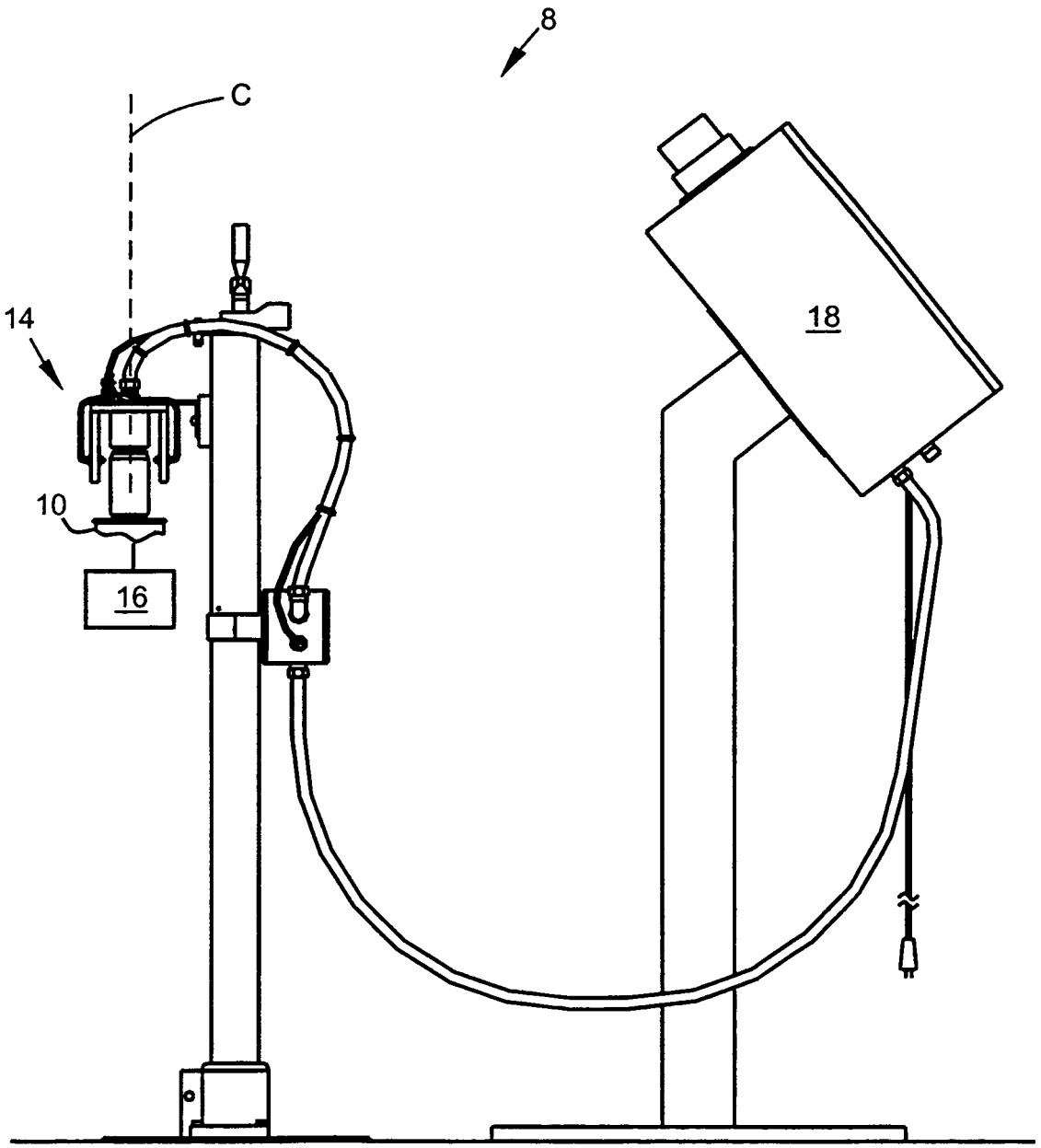


FIG. 3

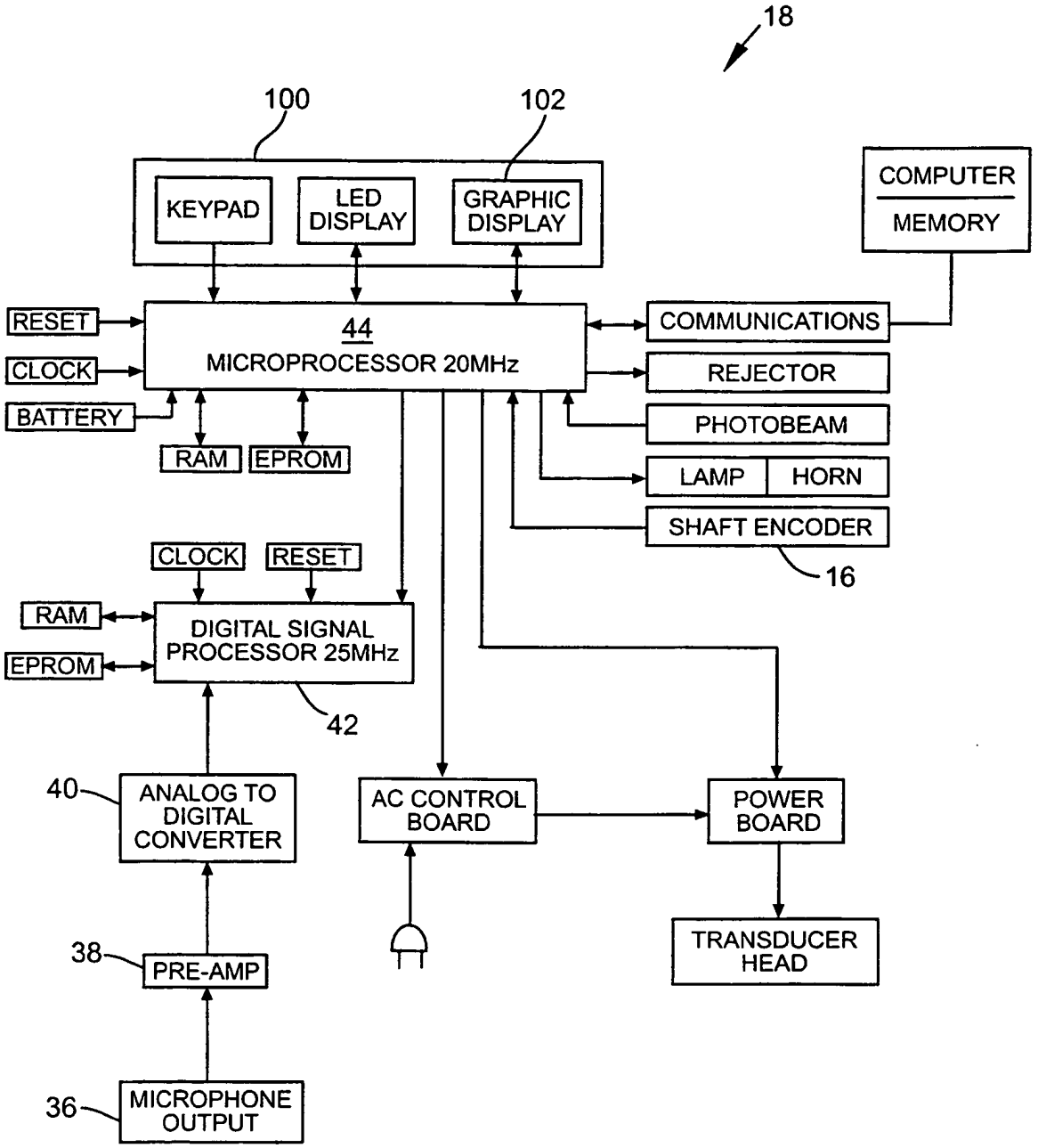

18
100
102
KEYPAD
LED DISPLAY
GRAPHIC DISPLAY
COMPUTER
MEMORY
RESET
CLOCK
BATTERY
44
MICROPROCESSOR 20MHz
COMMUNICATIONS
REJECTOR
PHOTOBEAM
LAMP
HORN
SHAFT ENCODER
16
RAM
EPROM
CLOCK
RESET
RAM
EPROM
DIGITAL SIGNAL PROCESSOR 25MHz
42
40
ANALOG TO DIGITAL CONVERTER
AC CONTROL BOARD
POWER BOARD
TRANSDUCER HEAD
38
PRE-AMP
36
MICROPHONE OUTPUT

FIG. 4

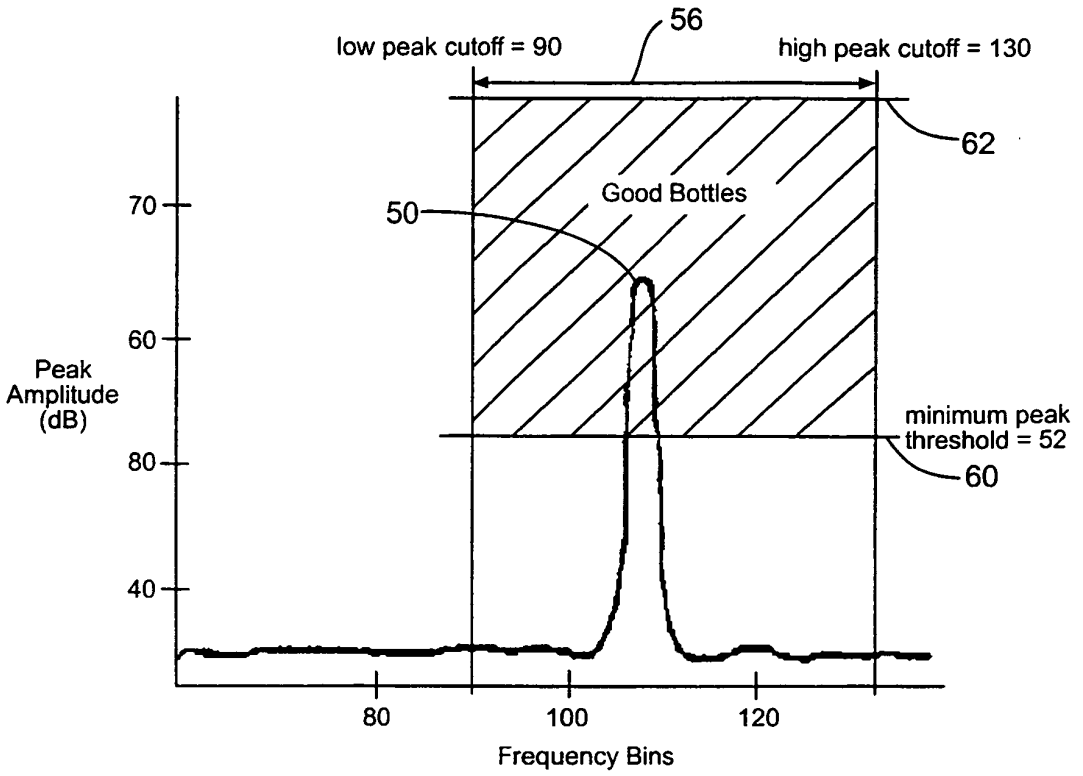

56
low peak cutoff = 90
high peak cutoff = 130
62
Good Bottles
50
70
60
Peak
Amplitude
(dB)
80
40
minimum peak
threshold = 52
60
80
100
120
Frequency Bins

FIG. 5a

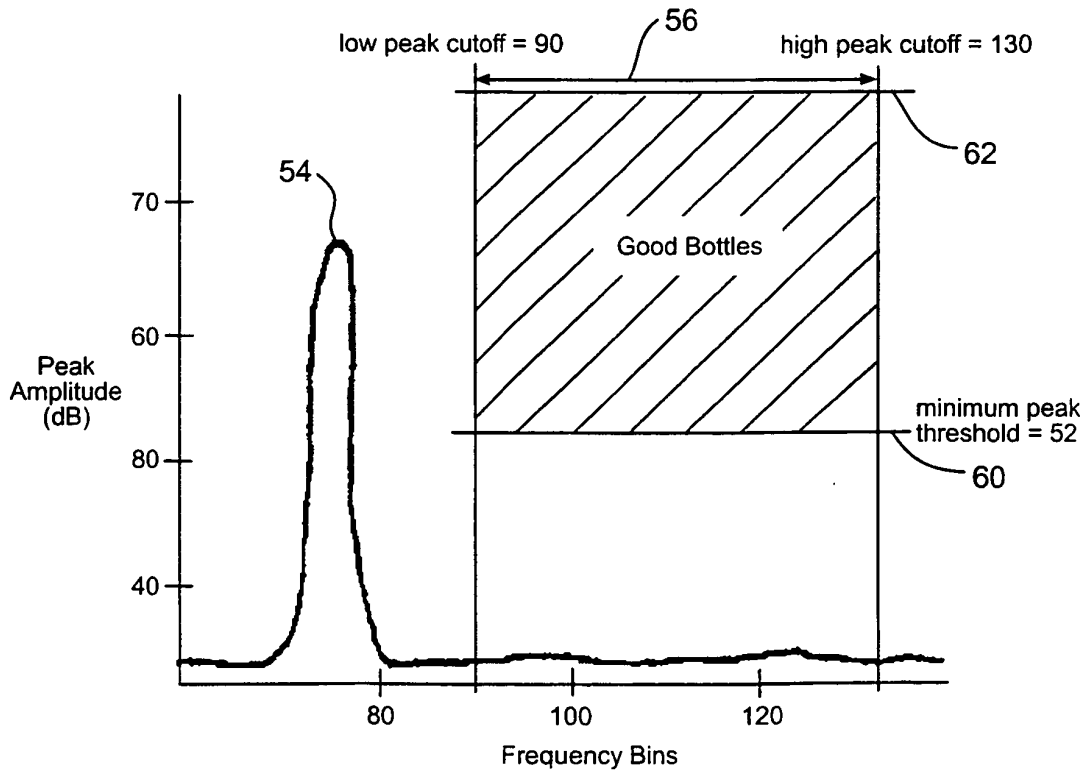

56
low peak cutoff = 90
high peak cutoff = 130
62
54
Good Bottles
70
60
Peak
Amplitude
(dB)
80
40
minimum peak
threshold = 52
60
80
100
120
Frequency Bins

FIG. 5b

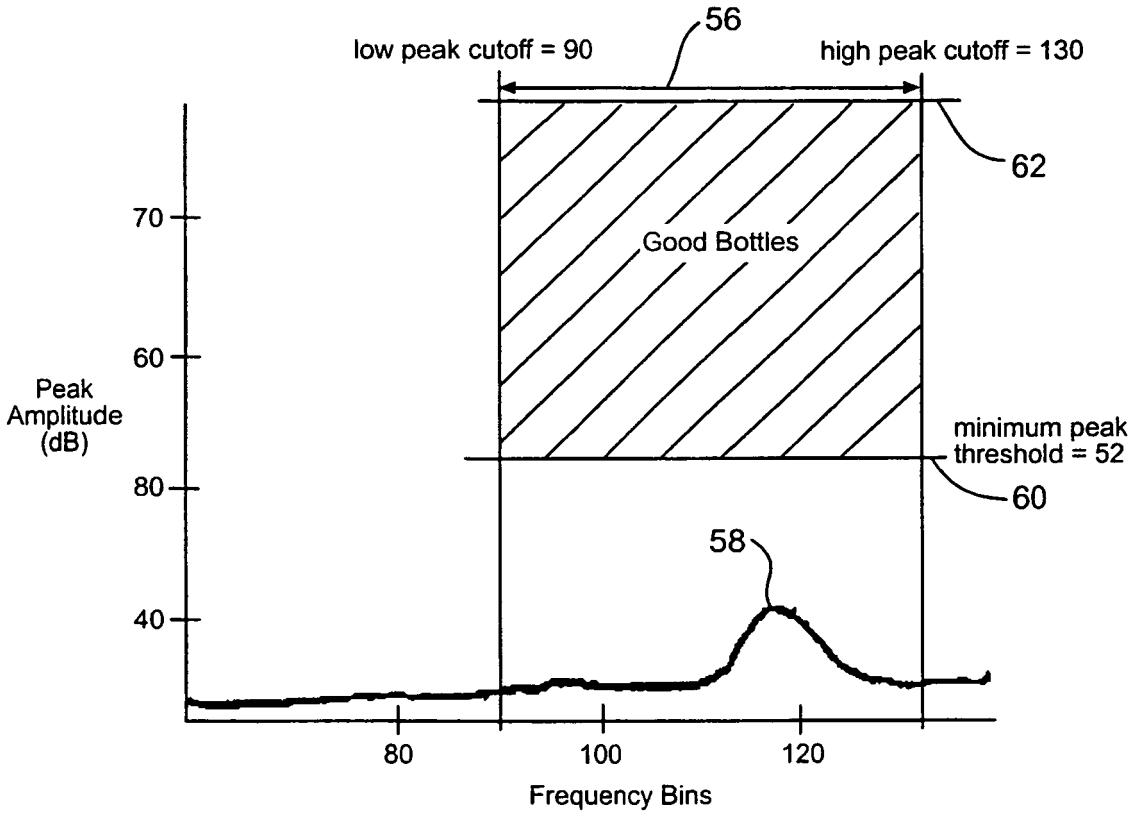

56
low peak cutoff = 90
high peak cutoff = 130
62
Good Bottles
minimum peak
threshold = 52
60
58
70
60
80
40
Peak
Amplitude
(dB)
80
100
120
Frequency Bins

FIG. 5c

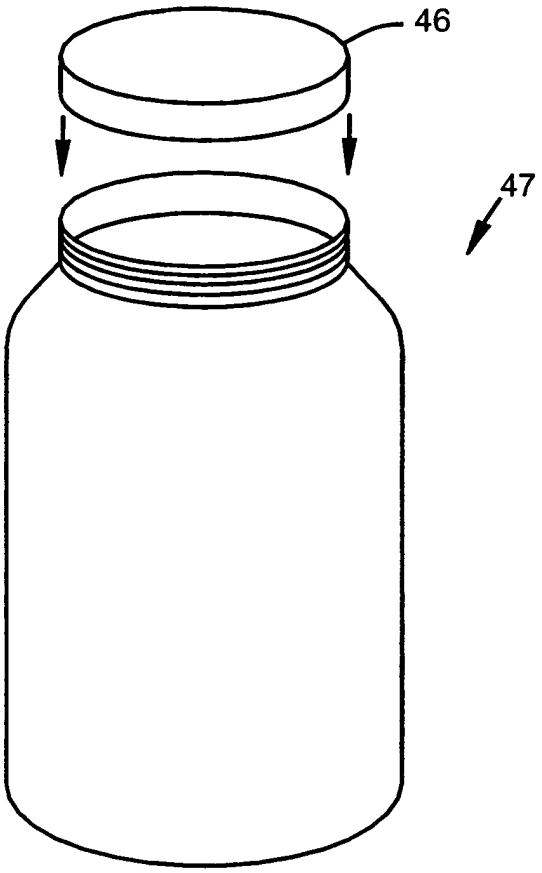


FIG. 6a



FIG. 6b

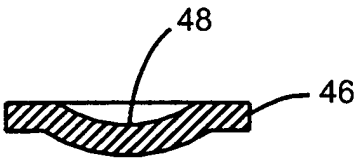


FIG. 6c

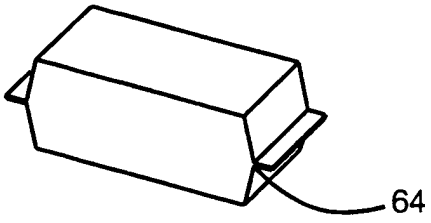


FIG. 8

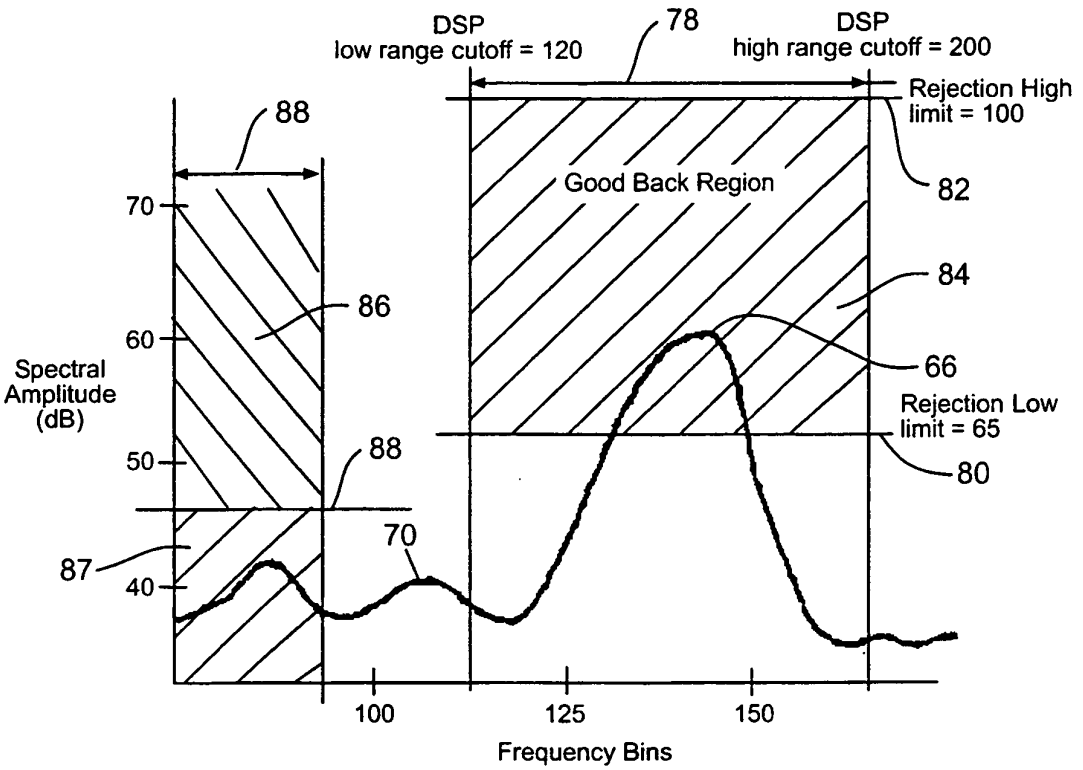

DSP
low range cutoff = 120
78
DSP
high range cutoff = 200
Rejection High
limit = 100
82
88
Good Back Region
70
86
84
60
66
Spectral
Amplitude
(dB)
Rejection Low
limit = 65
50
88
80
70
87
40
100
125
150
Frequency Bins

FIG. 7a

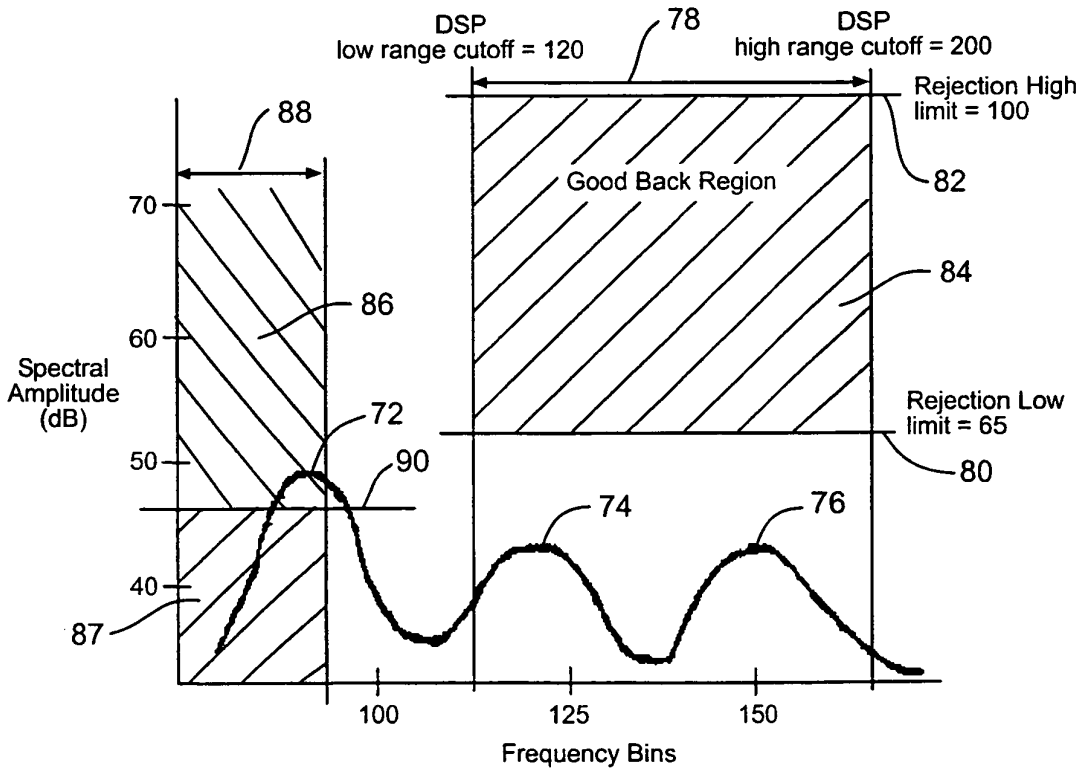

DSP
low range cutoff = 120
78
DSP
high range cutoff = 200
Rejection High
limit = 100
88
82
Good Back Region
70
86
84
60
Spectral
Amplitude
(dB)
72
Rejection Low
limit = 65
50
90
80
74
76
40
87
100
125
150
Frequency Bins

FIG. 7b

FIG. 9

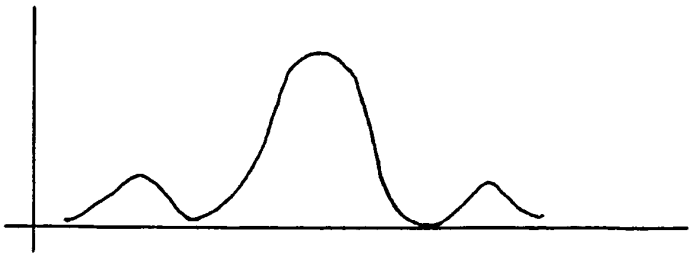


FIG. 10

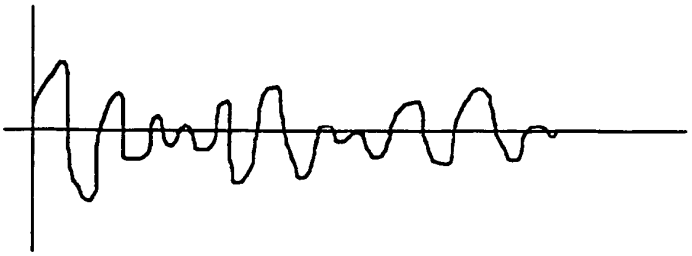


FIG. 11

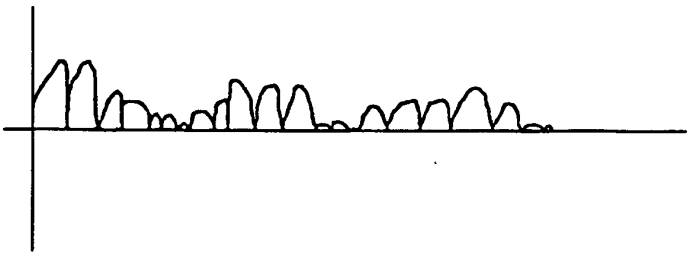


FIG. 12

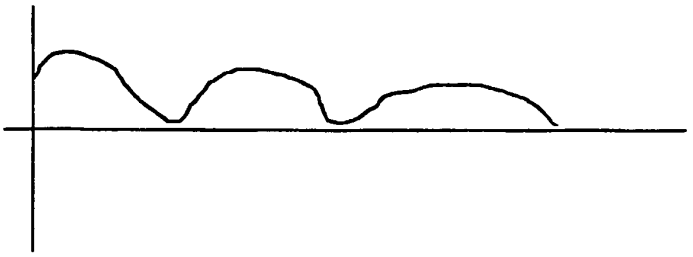


FIG. 13

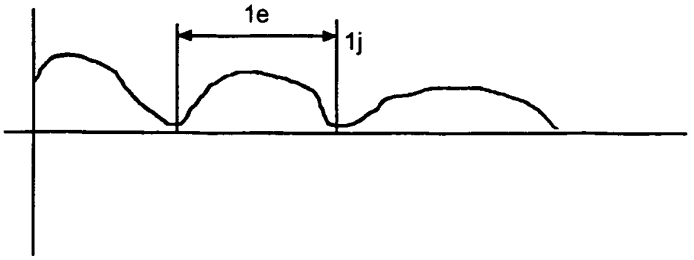
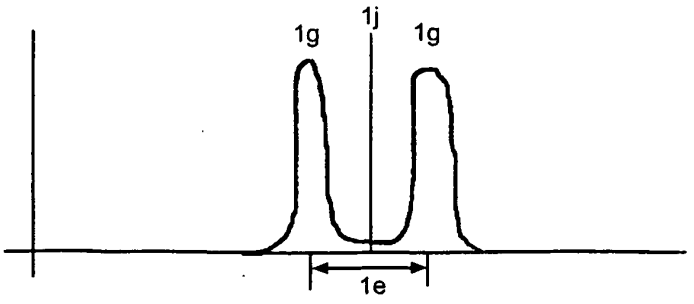


FIG. 14



REFERENCES CITED IN THE DESCRIPTION

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